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ABSTRACT

To investigate the relationship between lead levels and behavioral problems in children, hair lead levels were compared in a group of children (N=26, mean age 10.73) judged by teachers to have behavioral problems with a control group (N=29, mean age 8.68) judged not to have behavioral problems. There were no significant differences between groups in socioeconomic status, sex, or ethnic group distributions. Each child was rated by his/her teacher on the Walker Problem Behavior Identification Checklist (WPBIC). Behavior problem Ss had significantly higher hair lead levels, and lead correlated significantly and positively with the WPBIC scales measuring distractibility, aggression, disturbed peer relations, and immaturity. (Author/CL)

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# "Low Lead Levels and Behavior Problems in Children"

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"Low Lead Levels and Behavior
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Children who survive lead poisoning are at risk for severe behavioral disorders resulting from damage to the central nervous system (Byers & Lord, 1943). More recent research has suggested that among children with lead levels below those associated with overt lead poisoning behavioral disorders may also occur, albeit types more difficult to define. Low lead levels previously thought harmless are now being associated with hyperactivity, impulsiveness, and short attention span (David et al., 1972; 1976; Wiener, 1970), negative ratings by teachers on classroom behavior (Needleman et al., 1979; Phil & Parkes, 1977), school failure due to behavioral and learning problems (de la Burde & Choate, 1975), and mental disorders (Albert et al., 1974).

Excessive exposure to lead is a major pediatric health problem nationwide. Data from the Environmental Health Services Division, Center for Disease Control, indicate that from 1973 to 1978, among 2,380,942 children screened by projects funded under the Lead Based Paint Poisoning Prevention Act, 162,580 had elevated lead levels; 20,944 were diagnosed as lead poisoned. Since nationwide screening began, lead poisoning in children has declined, but elevated lead levels remain prevalent. Some urban areas report the condition in 20 percent of the children (Lin-Fu, 1980). Although conceived as primarily an urban concern, children living in rural areas are not spared from this health problem. A survey of 135 rural children from the Upper Cumberland Region of Tennessee revealed that 20 percent had elevated lead levels (Marlowe & Errera, 1981).

This study had two major purposes. The first purpose was to compare lead levels in a group of children with behavioral problems to lead levels in a control group. The second purpose was to explore the relationships between lead levels and teacher's ratings of children on the Walker Problem Behavior Identification Checklist (Walker, 1970).

## Methods

### Subjects

The 55 subjects in this study were drawn from four rural elementary schools (K = 8) in the Tennessee counties of Jackson (N = 9), Putnam (N = 20), and Smith (N = 26), These counties are situated in the Upper Cumberland Region of Tennessee, an economically depressed mountainous region geographically removed from any urban area.

Regular classroom teachers in the four schools were asked to nominate children they considered to be classroom behavioral problems. Parents of the children were then contacted and asked to permit their child to participate in the study. The school records of the children receiving parental permission were then reviewed to determine whether there was a known or highly probable medical reason for a behavioral disorder, e.g., brain injury. On the basis of this review, children with "probable cause" were removed from the study. In addition, any child with a history of diagnosed lead poisoning was excluded from the sample study. Only children with unremarkable medical histories for behavioral disorders were assigned to the behavior problem group (N = 26).

The control subjects (N = 29) were randomly drawn from the regular classrooms in the four schools in which behavior problem children had been nominated. Interviews with the regular classroom teachers indicated average or above average classroom behavior and conduct for each control subject.

None of the control children and one of the behavior problem children had histories of pica, the behavioral habit of ingesting inedible materials, such as clay, paper, plaster, and paint. Pica has been shown to substantially contribute to elevated lead levels and/or lead poisoning.

Table 1 shows the relevant demographic data for the two resulting groups of subjects. There were no significant differences between the groups in socio-economic status or in the sex and ethnic group distributions. The groups did differ significantly in age with the mean age in the behavior problem group 10.73 and the control group 8.68 ($p < .001$). This age variation occurred because of a greater willingness of control group parents with younger children to consent to the study

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Insert Table 1 about here

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Classification of Lead Levels

Children were asked to submit a small sample of hair (about 400 mg.) for trace mineral analysis. Hair samples were collected from the nape of the child's neck, as close to the scalp as possible, by the senior researcher using stainless steel scissors. The hair samples were then submitted to a state licensed clinical laboratory where they were analyzed with three instruments -- the atomic absorption spectroprotometer, the graphite furnace and the induction coupled plasma torch -- to determine the subject's lead levels.

Precise laboratory techniques were used to assure reliability of results and to meet reproducibility requirements. These included:

1. A blind sample was run from the initial steps through the entire procedure to assure reproducibility of methods.

2. At least one of every three tests was a standard. Working standards were made to assure proper values.

3. The in-house pool was completely remade and analyzed monthly to eliminate the possiblity of precipitating elements and to assure reproducibility.

4. Temperature and humidity were controlled to assure reliability and consistency of the testing instruments.

5. The hair samples were weighed to the thousandths of a gram (.001 g is equal to approximately four hairs, one inch (.0254 m) long); and only Volumetric Flasks, the most accurate available, were used for diluting the ashed sample.

6. Lot number control sheets for all reagents were used to assure uniformity. Records are kept and available for inspection.

7. All glassware was acid washed in-house before use and between each use including acid pre-washed disposable test tubes.

8. The water used was virtually mineral free, rated at 18+ MEG.

Reports summarizing the findings of the hair analysis for each subject were received from the laboratory subsequent to analysis. The report listed both the observed hair lead level and the suggested upper limit for hair lead and plotted the level in relation to the upper limit.

Hair: A Useful Diagnostic Tool

Every part of the human body contains at least a few atoms of every stable element in the periodic table. Although a large number of these elements are found in detectable amounts in human tissue, blood, and urine, hair, in particular, contains a higher concentration of many of these elements. Trace

elements are accumulated in hair at concentrations that are generally higher than those present in blood serum, provide a continuous record of nutrient mineral status and exposure to heavy metal pollutants and may serve as a probe of physiologic functions (Gordus, 1973; Maugh, 1978). Scalp hair has several characteristics of an ideal tissue for epidemiologic study in that it is painlessly removed, normally discarded, easily collected, and its contents can be analyzed relatively easily (Hammer et al., 1971).

The best results have been obtained with heavy metal pollutants such as lead. Numerous investigations world wide have shown that concentrations of lead and other heavy metals in the hair provide an accurate and relatively permanent record of exposure, and that there is a strong correlation between concentrations in hair and concentrations in internal organs (Kyle & Pease, 1966; Schroeder & Nason, 1969).

The classification of lead exposure to hair lead levels has been validated in a number of other studies. Hair lead levels are elevated in children with chronic lead poisoning (Kopito et al., 1967) and in children with elevated blood lead levels (Pueschel et al., 1972). Hair lead levels also vary in relation to the concentration of lead in housedust (Creason et al., 1975) and in relation to location proximity to a major lead processor (Roberts et al., 1974) and to metallic based pesticides and fertilizers (Hutchinson et al., 1973).

Walker Problem Behavior Identification Checklist

The Walker Problem Behavior Identification Checklist (WPBIC) is a screening device designed for elementary teachers in selecting children

with behavior problems who should be referred for further psychological evaluation, referral, and treatment. The WPBIC consists of 50 observable operational statements of classroom behavior that might limit a child's adjustment in school. Differential score weights are assigned to each statement based on their influence in handicapping a child's adjustment. Factoring the 50 items, 14 items relate to acting-out (aggressive and disruptive behavior), five items relate to withdrawal (socially avoidant and passive behaviors), 11 items relate to distractibility (poor attentiveness and restlessness), ten items relate to disturbed peer relations, and ten items relate to immaturity.

Standardized on 534 elementary age children, the mean raw total score was 7.76 with a standard deviation of 10.53. One standard deviation above the mean separates disturbed behavior from nondisturbed behavior. Walker (1970) reported the split half reliability of the scale at .98 and the difference between the means of disturbed and nondisturbed children on the scale significant beyond the .001 level.

In this study, classroom teachers were instructed how to fill out the scale by the senior researcher. All teacher ratings were based on observations of the child's classroom behavior during the last two month period.

## Results

The two groups of children were compared for hair lead concentrations. As shown in Table 2 the mean concentration for the behavior problem group was considerably above that of the control group. The behavior problem group had a mean hair lead of 11.61 parts per million (ppm.) while the control group had a mean hair lead of 6.51 ppm. The data were then analyzed with the *t* test

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Insert Table 2 about here

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for two independent samples design of SPSS (Nie et al., 1975), yielding a statistically significant $t$ value ($t = 3.23, 53, p < .001$) indicating that the variation between the two means was unlikely to have occurred by chance.

Fifteen ppm. is considered to be the normally tolerated limit of hair lead (Doctor's Data, 1977). The distribution of hair lead concentrations in the two groups is shown in Table 3. Six of the behavior problem children had lead concentrations above the normally tolerated limit while none of the control children exceeded 15 ppm. No children showed extreme concentrations associated with lead poisoning (< 100 ppm.).

Insert Table 3 about here

The two groups of children were then compared for behavioral scores on the WPBIC. The behavior problem group scored significantly higher than controls on four scales and the total scale of the WPBIC. Mean WPBIC total scale raw scores were 23.13 for the behavior problem group and 7.48 for the controls ($p < .001$). A total scale raw score of 21 or more is considered to denote disturbed behavior; thus, the behavior problem group secured a mean within the disturbed range.

Insert Table 4 about here

The results of the behavioral checklists were then analyzed relative to the 55 children's lead levels with the Perason product correlation procedure of SPSS (Nie et al., 1975). Table 5 contains the correlations between the five scale and total scale scores on the WPBIC and the subject's lead levels.

Insert Table 5 about here

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Lead levels correlated significantly and positively with the behavioral factors of acting out (.37), distractibility (.45), disturbed peer relations (.57), immaturity (.29), and total scale score (.50).

Table 6 presents significant correlations between each of the 50 items on the checklist and the subjects' lead levels. Overall, 20 significant

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Insert Table 6 about here

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correlations occurred. Eight of the 11 items denoting distractibility, six of the 10 items denoting disturbed peer relations, four of the 14 items denoting acting out, and two of the 10 items denoting immaturity were positively and significantly correlated. None of the five items dealing with withdrawal correlated significantly.

## Discussion

While not establishing an etiological relationship, the data of this study shows an association between increased lead concentrations and behavioral deficits in children. Children identified as behavioral problems by teacher nomination and WPBIC behavioral measures were significantly higher in lead than a control group, and the study's correlational data indicated that an increase in lead levels resulted in higher scores on the WPBIC. The $R^2$ value between lead level and total scale score was 0.2554, thus indicating that 25 percent of the variance of the total scale score may perhaps be accounted for by the children's lead levels.

Although six of the behavior problem children had elevated hair lead levels, the mean lead level for the behavior problem group fell within the accepted normal range. Recent studies have suggested, however, that there

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may be no such thing as a threshold level of lead in the body, that is, a quantity below which there are no toxic effects (David, 1978; Needleman et al., 1979). David's and Needleman's findings suggest that lead exerts its effect over a continuum and that it causes behavioral dysfunctions at even very low levels.

Official recognition of lead's effects can be seen in the steadily downward revision of the threshold level of lead in the body by health authorities. At one point in time, using blood lead as an index of exposure, the threshold level was considered to be 60 micrograms per 100 cc of blood. The U.S. Surgeon General then recommended in 1970 that 40 micrograms per 100 cc of blood be the threshold level. In 1975 the figure was revised downward to 30 micrograms per 100 cc of blood, but the Center for Disease Control cautioned when proposing this new figure that, at that level, there is a danger of clinical lead poisoning. Some authorities now assert that 20 micrograms per 100 cc of blood represents an unsafe and harmful level (Wessel & Dominski, 1978).

It is remarkable that eight of the 11 checklist items dealing with distractibility correlated positively and significantly with lead. Distractibility is often interrelated with hyperactivity (Kauffman, 1981), and previous studies have implicated low level lead exposure as a causative factor in at least some cases of hyperactivity (David et al., 1972; 1976; Wiener, 1970). It should be noted that a number of other investigators (Rummo, 1974; Landrigan et al., 1975; Baloh, 1975) who expressly looked for evidence of lead induced hyperactivity in children with low elevated lead levels failed to find any significant effects. It should be considered, however, that given the likely subtle nature of some of the behavioral effects probable at low levels of lead exposure, one would not expect to find striking differences in every instance.

No previous experimental research has reported a relationship between low level lead exposure and acting out aggressive behavior in children. The question of low level lead induced aggression is intriguing but more than usually speculative given the correlational nature of the data. It is worth noting however, that lead has been reported to effect various neurotransmitter levels (Hradina et al., 1980) which in turn are viewed as integral in some current theories of aggression (Eichelman, 1979). The possibility that low lead levels induce aggression also recieves credence from the observation that hostile and destructive behavior is one behavioral pattern observed in children who survive lead poisoning (Byers & Lord, 1943).

Low lead levels have also been associated with childhood mental disorders, often characterized by disturbed interpersonal relationships (Albert et al., 1974). In the present study six of the ten checklist items dealing with disturbed peer relations correlated significantly with lead. These correlations may also be viewed, perhaps, as a negative concomitant characteristic of children exhibiting distractibility and/or aggression. Typically, such children do not get along with their peers. They are aware they have socialization problems and so are their teachers and other children.

The immaturity scale also correlated significantly with lead. There has been limited research into this relationship, although developmental regression, like distractibility and aggression, is one result of lead poisoning. One previous study (Kotok et al., 1977) reported a control group scored higher than a group of children with elevated lead levels on social maturity ($p < .10$).

A number of limitations of this study must be considered. First, with no more than 55 children in the sample, this is a rather modest study and doubts

may arise on how representative the findings are.

Second, results of the comparisons between the two groups need careful interpretation since observed differences in lead levels could have derived from variation between the groups in age (controls were approximately two years younger). In defense of the comparative data, it should, however, be noted that the younger the child the greater the risk for lead absorption (Center for Disease Control, 1978). The vast majority of children identified as lead poisoned have been under six years of age and elevated lead levels occur more frequently in this age group. Factors making younger children more vulnerable to lead exposure include their relatively inefficient metabolism, excretory pathways, and immunological system (King, 1971) and a smaller skeletal structure to store lead, thus leaving a larger pool of mobile lead to effect the soft tissues (Barry, 1975). Additionally, the high lead content of dust and dirt poses a greater problem for the younger child with normal hand to mouth activity, and lead content in ambient air is greater at the height at which younger children breathe (Darrow, 1974). Finally, a previous study of lead levels in children from the Upper Cumberland Region of Tennesee (N = 67) reported a nonsignificant relationship between age and subjects' lead levels (Marlowe et al., in press).

The findings of this study support the growing body of studies which have associated low or moderate level lead effects with neurobehavioral dysfunctions. These studies have linked low or moderate lead levels to mental retardation, impaired IQ, deficits in visual, fine, and gross motor coordination, behavioral disorders, and hyperactivity, findings previously reported as secondary results of lead poisoning (Lin-Fu, 1979). The data

of these studies indicate the continuing need to reexamine lead poisoning concentrations because concentrations of lead previously thought harmless have been consistently associated with neurobehavioral impairments and may now have to be considered lead poisoning. Reviewing these studies the U.S. Environmental Protection Agency (1978) concluded that neural damage does exist in children at low or moderate lead levels.

Also warranting further examination is the subsequent neurobehavioral development of children who receive intervention to reduce lead levels. David and others (1976) reported behavioral gains in hyperactive children treated with lead chelating agents, and Phil et al. (1979) reported improvements in the behavior of learning disabled children who received medical and nutritional counseling to reduce lead levels. Based upon present evidence, reduction of lead intake from all sources, family education for all, correction of nutritional deficiencies where they exist, and careful monitoring of the child will usually suffice in reducing lead levels (Center for Disease Control, 1978).

Special educators and other school personnel can play a significant role in the detection of excessive lead exposure in children through awareness of its symptoms. These include irritability, listlessness, anemia, clumsiness, loss of appetite, chronic abdominal pain, and headaches. Since such symptoms are also associated with other illnesses, e.g., viral infections, educators should also be aware of factors that make a child a high-risk candidate for excessive exposure. These include living in a dilapidated substandard house which often contain peeling lead based paint and plaster, residential proximity to heavy traffic patterns and/or smeltering emissions, having the habit of

pica, and inadequate nutrition. Additionally, educators can have parents complete the Lead Exposure Checklist (Marlowe, 1981) in order to obtain detailed information about the child's habits and lead hazards in his/her environment.

Children presenting symptomatology of excessive lead exposure and whose habits and environment pose substantial lead risks should be screened to determine the seriousness of their lead exposure. Initial testing for the presence of lead can be detected through an "erythrocyte protoporphyrin" (EP) test or by hair analysis. In the EP test a drop of blood from the child's finger is placed on a scanning machine which records the amount of lead in the blood.

Educators should introduce health curriculum on lead exposure prevention. One such curriculum material is The Adventures of Lead Commander, a coloring book developed for public school dissemination through the President's Committee on Mental Retardation (Marlowe & Marlowe, 1981). This material describes the efforts of Lead Commander, an outer space hero, who with the help of children wages battle against lead pollution on earth.

Knowledge regarding excessive lead exposure and its effect on neurobehavioral development has never been demanded in personnel-preparation programs in special education. Any major change in this direction should be predicated on a much broader research base relating to excessive lead exposure to educational outcomes than presently exists. It remains true, however, that the limited knowledge available regarding the etiological role of lead exposure in educationally handicapping conditions is not being utilized. It may be that there are some lead exposed children in special education programs whose problems can and

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should be better understood. It is hoped that these concluding remarks will result in special educators becoming more aware of this major pediatric health problem. The alternatives in terms of lead's continuing neurotoxic effects on children are clearly unacceptable.

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Table 1 - Demographic Characteristics of 2 Groups of Children

| | N | Sex M/F | Age (yr.) Mean ± S.D. | Age (yr.) Range | Ethnic Group Caucasian | Ethnic Group Other |
|---|---|---|---|---|---|---|
| Behavior problem group | 26 | 17/9 | 10.73 2.27 | 6-14 | 26 | 0 |
| Control group | 29 | 20/9 | 8.68 1.71 | 6-13 | 29 | 0 |

Children in each group came equally from social classes 4 and 5 as defined by Hollingshed and Redlich (1958).

Table 2 - Comparison of Hair-Lead Concentrations Among 2 Groups

| Group | N | Hair-lead (ppm.) (mean t S.D.) | T value* |
|---|---|---|---|
| Behavior problem group | 26 | 11.61 ± 7.65 | 3.37** |
| Control group | 29 | 6.52 ± 2.62 | |

* two tailed
** $p < 0.001$

Table 3 - Distribution of Hair-Lead Concentrations for 2 Groups of Children

| | Hair-Lead Range (ppm.) | | |
|---|---|---|---|
| Group | 2.0 - 15.0 | 15.1 - 30.0 | 30.1 - 35.0 |
| Behavior problem group | 20 | 5 | 1 |
| Control group | 29 | 0 | 0 |

Table 4 - Comparisor of WPBIC Scores Among Two Groups

| Scale | Behavior Problem Group | Control Group | T Value* | Raw Score Denoting Disturbed Behavior |
|---|---|---|---|---|
| Total Scale | 23.15 ± 10.97** | 7.48 ± 10.49 | 5.41 | 21 |
| Acting-Out | 7.03 ± 5.34** | 2.34 ± 4.63 | 3.49 | 8 |
| Withdrawal | 0.92 ± 2.01 | 0.37 ± 0.86 | 1.32 | 5 |
| Distractibility | 7.65 ± 2.92** | 3.27 ± 4.18 | 4.45 | 6 |
| Disturbed Peer Relations | 4.28 ± 3.50** | 0.82 ± 1.60 | 4.76 | 3 |
| Immaturity | 3.46 ± 3.51** | 0.65 ± 1.87 | 3.75 | 3 |

* two tailed
** $p > 0.001$

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Table 5 - Correlations Between WPBIC Scales and Children's Lead Levels (N=55)

| | Acting-Out | With-drawal | Distract-ibility | Disturbed Peer Relations | Immaturity | Total Scale |
|---|---|---|---|---|---|---|
| Lead | .37 * | .07 | .44* | .56* | .29** | .50* |

*p>0.01
**p>0.05

Table 6 - Significant Correlations ($p < .05$) WPBIC and Lead Levels for Children (N=55)

| | ACTING OUT | | | | DISTRACTIBILITY | | | | | | | | DISTURBED PEER RELATIONS | | | | | IMMATURITY | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Becomes hysterical, upset, or angry when things do not go his way | Makes distrustful or suspicious remarks about actions of others toward him | Argues and must have the last word in verbal exchanges | Reacts with defiance to instructions or commands | Does not conform to limits on his own without control from others | Perfectionistic: Meticulous about having everything exactly right | Has difficulty concentrating for any length of time | Underachieving: Performs below his demonstrated ability | Disturbs other children: teasing, provoking fights, interrupting others | Does not complete tasks attempted | Easily distracted away from the task at hand by ordinary classroom stimuli | Approaches new tasks and situations with an "I can't do it" response | Comments that no one understands him | Will destroy something he has made rather than show it or ask to have it displayed | Repeats one idea, thought, or activity over and over | Refers to himself as dumb, stupid, or incapable | Stutters, stammers, or blocks on saying words | Is hypercritical of himself | Apologizes repeatedly for himself and/or his behavior | Weeps or cries without provocation |
| LEAD | .25 | .44 | .38 | .25 | .33 | .46 | .24 | .40 | .25 | .24 | .29 | .34 | .35 | .39 | .33 | .46 | .38 | .60 | .33 | .30 |

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